Technical Paper

Aluminum Wire Drawing Filtration

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The paper is an overview of the process, component selection and the various clarifiers for an effective aluminum wire drawing filtration system. Basic concepts are described for clarification of mineral oil and water-soluble applications from Rod Breakdown to Ultra Fine Wire Drawing using retention, media filters, self-cleaning conveyor tanks, and automatic self-cleaning centrifuge.

THE BASICS

The primary function of the lubricant is to reduce the coefficient of friction between the wire and die as well as heat removal at the die. Ideal conditions allow the wire drawing machine to operate at maximum speed to provide maximum die life, and to produce a bright finished wire with minimum consumption of lubricant.

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The majority of aluminum wire drawing is accomplished using mineral oil based lubricants for a variety of applications which include Rod Breakdown, Intermediate, Fine Wire, and Ultra Fine Wire. The lubricants vary in formulation of the oil, viscosity, additives, and other factors. Some Intermediate, typically Fine and Magnet Wire, applications have used a water-soluble lubricant and a number of installations are now using water-soluble coolants for rod breakdown of specific alloys.

A range of new mineral oil viscosities for various applications is shown below:

APPLICATION	MINERAL OIL VISCOSITY*	WATER SOLUBLE
Rod Breakdown	750 SSU @ 100°F (38°C)	10-15%
Heavy Intermediate	400 SSU @ 100°F (38°C)	6-8%
Intermediate	150 SSU @ 100°F (38°C)	3-5%
Fine Wire Drawing	85 SSU @ 100°F (38°C)	2-3%
Ultra Fine/Magnet Wire	42 SSU @ 100°F (38°C)	0.5-1%

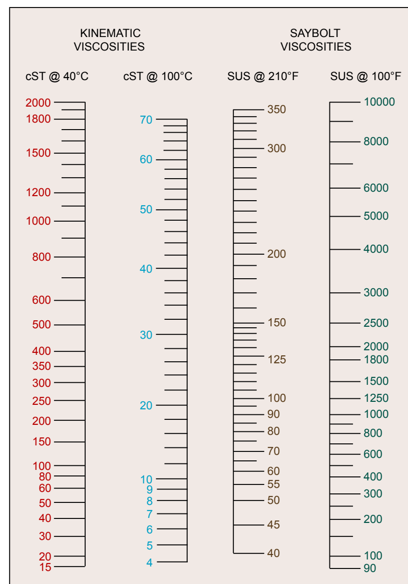
*Viscosity of new oil

(As a comparison, water is 32 SSU @ 100°F)

Oil viscosity is normally expressed in SSU (Saybolt Seconds Universal) at 100°F (38°C). Other standards such as Centistokes and Centipoise are also used. Figure #1 shows a conversion chart for the various standards. Remember that the higher the viscosity, the " thicker " the oil.

All types of wire drawing lubricants benefit from removal of metallic particles and other suspended solids. Removal of these materials reduces the rate of the chemical reactions which break down the lubricants and lead to poor wire finish. In addition, when metallic oxide is present in the lubricant, scratching, die wear, and wire breaks can result. Removal of oxide particles should be considered the primary reason for filtration of lubricants used in aluminum wire drawing.

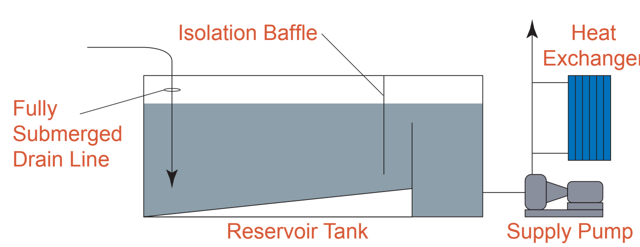
Kinematic & Saybolt Viscosity Table
Figure 1



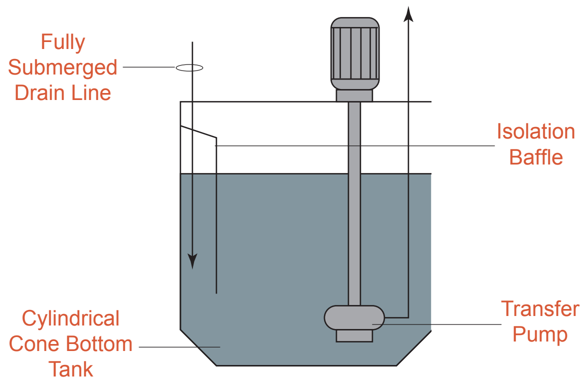
FILTRATION SYSTEM CONFIGURATION

Whenever possible, allow gravity flow from the wire machine(s) to the filter system with the drain line totally submerged in the lubricant and properly isolated especially for mineral oil applications. Mineral oil exhibits unique characteristics relative to fluid handling and must be properly handled to prevent air entrapment within the oil. Figure #2 shows suggested return piping to prevent or eliminate this problem. If it is not possible to gravity flow directly into a filter system, a transfer sump, as shown in Figure # 3, can be successfully used if properly designed.

Gravity Drain Into Rectangular Tank
Figure 2



Gravity Drain Into Transfer Sump
Figure 3



MAJOR COMPONENT SELECTION (MINERAL OIL)

The success of component selection is based on viscosity control by effectively removing suspended and settled aluminum solids. As oil becomes dirty the viscosity rapidly increases which greatly inhibits the performance of pumps, heat exchangers, clarifiers, and the lubricating process. Therefore, it is critical to properly size all components for maximum efficiency relative to viscosity.

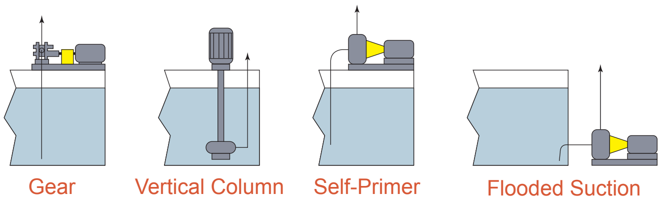
PUMPS

The preferred pump types as shown in Figure #4 would be a flooded suction, vertical column or gear type pump. A self-priming pump, while functional, may have difficulty priming if the oil is high viscosity and has entrained air.

Pumps should be selected for the lowest practical speed, 1150 RPM to 1750 RPM, Pumps operating at 3500 RPM should not be considered. Pump selections must also consider the following:

- Specific gravity of the oil.
- Oil viscosity @ 100°F (38°C).
- Maximum recommended oil viscosity @100°F (38°C) (obtain from manufacturer of the oil).
- Operating temperature of the process.
- Maximum recommended percent solids in suspension (obtain from manufacturer of the oil).
- Required discharge head (TDH) for the pump.

Pump Types
Figure 4



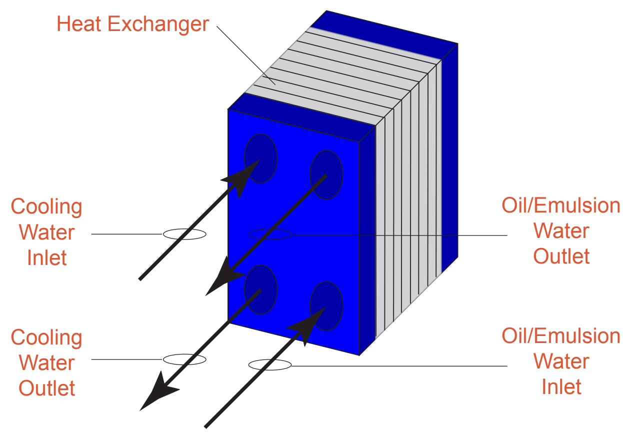
HEAT EXCHANGER

The majority of all wire drawing applications require mechanical cooling of the oil in order to satisfactorily draw wire. Typically, a range 95°F to 125°F is required, depending on the application.

The preferred type of heat exchanger is a plate and frame type, as shown in Figure #5. The unit offers numerous advantages over shell and tube heat exchangers, such as the ability to easily clean, prevention of cross-contamination between oil and cooling water, and the ability to easily add plates (surface area) for potential expansion.

As with the pumps, the viscosity of the oil must be considered for proper selection of the heat exchanger, as oil does not "shed" heat efficiently as in water-soluble applications.

Heat Exchangers
Figure 5



Other factors to be considered:

- Specific gravity.
- Specific heat.
- Thermal dissipation in BTU/HR.
- Desired operating temperature.
- Type of cooling water, temperature, and capacity in GPM (lpm).
- Pressure drop available.

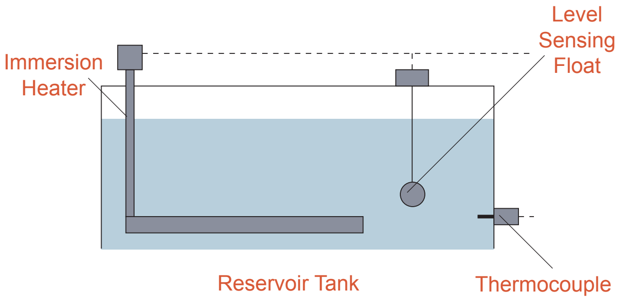
IMMERSION HEATER

When starting an oil lubrication system for aluminum wire drawing, it is desirable to warm the oil before beginning to draw wire. This will aid lubrication as the oil will flow to the dies more efficiently. Warming the oil is accomplished with a properly-designed immersion heater(s).

Referring to Figure #6, an immersion heater will maintain the desired oil temperature when wire drawing is not being performed and reduce the warm-up time when wire drawing is started. Heating also drives off water and moisture which is detrimental to the wire drawing process causing wire breaks, accelerated die wear, and poor finish on the wire. Adding heat also increases the ability of the oil to release suspended solids for effective removal by a clarifier. In all cases, low watt density heaters must be incorporated to prolong the life of the heater and prevent damaging the oil by intense heat in a concentrated area.

The use of steam heat via coils/plates or a heat exchanger is not recommended due to the possibility of steam or condensate contaminating the oil if a leak occurs.

Immersion Heater
Figure 6



VALVE SEALS

When designing any lubricant system, interaction of the lubricant with the component seals must be considered. Many lubricants contain active ingredients which can erode or swell seals. Either activity will compromise the integrity of the seals and lead to leaks and the inability to fully close valves. Elastomer compatibility studies should be performed on the lubricant to determine the best type of seal material to choose for system seals. Viton® seals are found to be compatible with most lubricants and will provide the longest seal life. The preferred choice for valves would be all iron-gate valves.

PIPING

Consideration relative to viscosity is critical to reduce head loss and pumping cost. Typically mineral oil applications will require piping one or two sizes larger than water-soluble applications for the same flow rate. Velocity calculations would be similar to those for water-soluble applications.

FILTRATION CONCEPTS (MINERAL OIL)

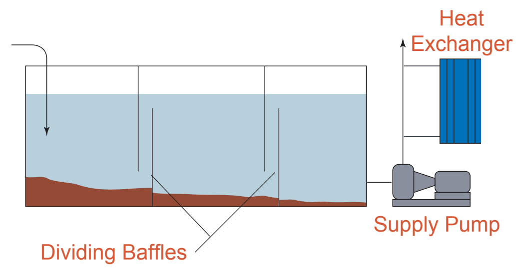
It is important to recognize that the oil should be considered a valuable tool which will provide long life with proper clarification and oil maintenance. As with all capital expenditures, proper maintenance is critical to ensure maximum return on investment. Proper filtration has been shown to extend oil life dramatically. The cost of a filtration system can be easily capitalized when unneeded oil recharges are considered.

Mineral oil systems can approach a life of over seven years with proper filtration and operating volume. Maintenance of oil systems would include frequent testing and evaluation of the oil, proper filtration, make up and proper additives for the oil.

RETENTION WITHOUT A CLARIFIER

Referring to Figure #7, this concept would require a large reservoir, at least 30 minutes times the flow rate, to provide effective clarification of the oil. The reservoir should incorporate baffling to promote settling; however, the negative effect allows the accumulation of aluminum fines, which displace the volume of oil allowing transfer of dirty oil to the machine(s). The tank will also require periodic removal of the oil and accumulated solids to maintain retention time for acceptable performance.

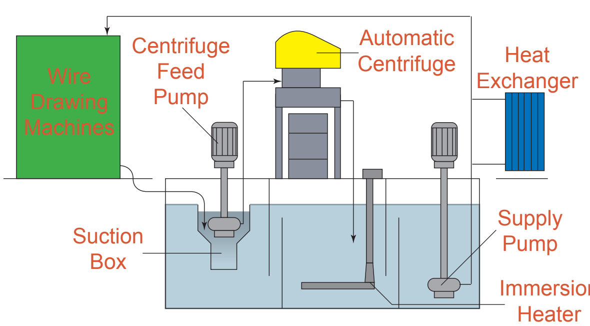
Retention Tank Without Clarifier
Figure 7



RESERVOIR TANK WITH SUCTION BOX AND CENTRIFUGE

A fully-automatic centrifuge would be used with a new or existing rectangular tank as shown in Figure #8. The dirty oil from the wire drawing machine(s) would drain by gravity into the suction box which would be installed in the dirty section of the tank. A filter feed pump would transfer the dirty oil and aluminum solids directly to the centrifuge on a bypass basis. Typically the suction box can be installed without removal of oil and does not displace any volume in the tank.

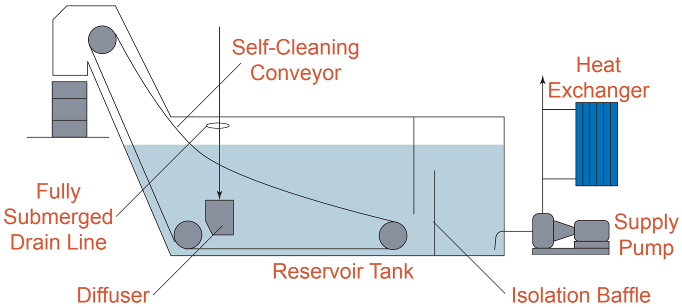
Reservoir Tank With Suction Box and Centrifuge
Figure 8



RETENTION WITH A SELF-CLEANING CONVEYOR SYSTEM

Referring to Figure #9, this concept is very effective due to the self-cleaning conveyor, which automatically removes accumulated solids into drums or hoppers for collection. Typically retention times should be in the range of 20 minutes times the flow rate for satisfactory results. Baffles are incorporated to separate the dirty section from the cleaner section of the tank. The conveyor is designed to run intermittently with specially-designed scraper flights to allow drainage of "free" oil into the system as opposed to being removed by the conveyor.

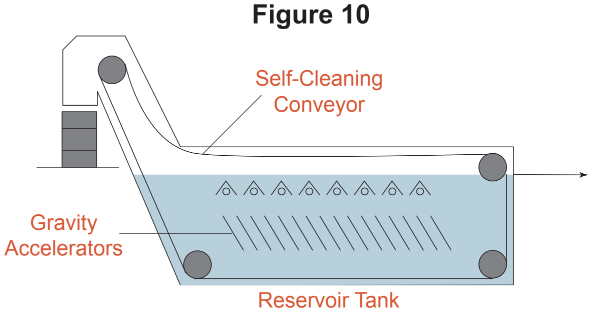
Self-Cleaning Conveyorized Tank
Figure 9



RETENTION WITH "HEAT AND HOLD"

Another efficient concept, as shown in Figure #10, is a two-compartment conveyor tank with the narrow compartment incorporating low watt density heaters with specially designed inclined plates whereby the oil is elevated to a safe operating temperature as recommended by the oil supplier. The temperature reduces the viscosity and promotes rapid settling of accumulated aluminum particles which are removed by the conveyor within this compartment. The main section of the tank incorporates a larger conveyor to remove the heavier particles which settle in the retention process. Typically an extended retention time is required whereby a percentage of the oil is transferred to the " heat and hold section."

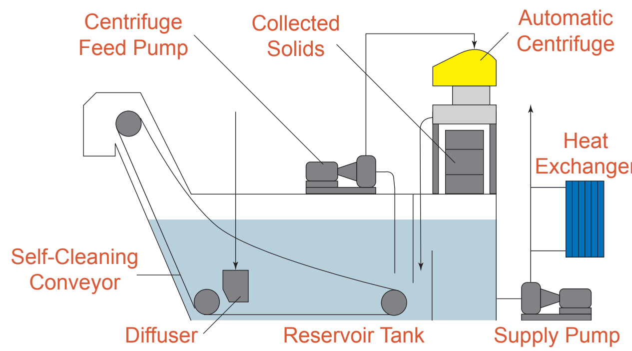
Heat And Hold
Figure 10



RETENTION WITH A SELF-CLEANING CENTRIFUGE

Referring to Figure #11, this concept works with or without a self-cleaning conveyor however, the self-cleaning conveyor offers numerous advantages as previously mentioned. A centrifuge, as shown in Figure #12, is by far the most efficient method of concentrating and automatically discharging solids in a relatively dry state. The centrifuge relies on centrifugal force to collect suspended particles towards the outside of a rotating bowl during the process cycle. The centrifuge then goes through a spin cycle to remove residual oil prior to discharge. The inlet feed to the

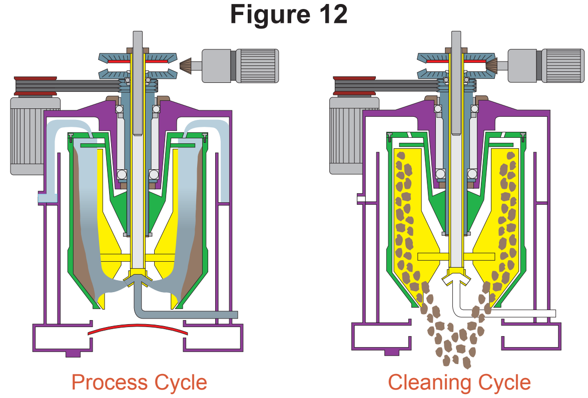
Self Cleaning Conveyorized Tank With Automatic Centrifuge
Figure 11



centrifuge is turned off during this process. The discharge phase efficiently removes accumulated solids by counter rotating the bowl and blades within the centrifuge to scrape accumulated material and discharge the same into drums or hoppers for collection. Modern centrifuges also have the ability to detect the buildup of solids at startup or during the process cycle, if over-accumulation of solids is present. At this point, the centrifuge goes through a cleaning cycle before going into another process cycle. Typically a centrifuge is sized for approximately 10% of the total system flow rate, operating very efficiently on a bypass basis.

Acceptable reservoir retention times would typically be in the range of 15 minutes times the flow rate in GPM (lpm).

Automatic Centrifuge
Figure 12



Automatic Self-Cleaning Centrifuge*

Customer "A" draws aluminum alloy rod and was replacing the oil every year. A centrifuge was added on a bypass loop, and the oil life was increased to over two and one half years. Monthly wire production from the machine also increased due to fewer wire breaks. This improvement in production was traced to reduced die plugging from the cleaner oil.

Customer "B" draws fine wire and recharged every six months due to plugging of the dies by fines. The oil was disposed of due to lack of space. The used oil was tested by the supplier and found to be suitable for use in all aspects except the fines content. Addition of a filtration system enabled the customer to achieve twice the tank life and reduced disposal costs dramatically. The overall effect of adding a filtration system is to significantly extend the useful life of a system. When the system is fully optimized, it is not unusual to get five years and more of service from a rod breakdown lubricant system. Typically adding an automatic centrifuge to a new or existing system will double the life of the oil.

Table 1 shows several systems and the levels they maintained in relevant testing. These systems have been in operation for a number of years.

MEDIUM TO LIGHT VISCOSITY OIL

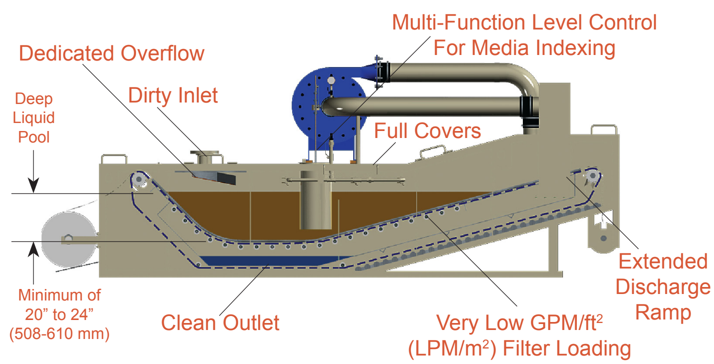
Many applications using light viscosity oil 100 SSU @ 100°F (38°C) to medium viscosity oil 400 SSU @ 100°F (38°C) can be efficiently handled using a deep bed horizontal configuration gravity filter sized properly relative to filter area.

The success is in the design of the filter incorporating a deep horizontal bed to generate an increased pressure drop across the media, extended drying ramp at the exit end of the filter, fully adjustable index mechanism for time and duration, as well as filter loading and at a very low GPM/ft^2 (LPM/m^2). The concept for the filter is shown in Figure 13.

Typically a flat bed air vacuum filter is not recommended with the lighter viscosity oils due to the mist generated from the air flow of the vacuum producer.

As in previous recommendations, the size of the reservoir tank and design of the tank is critical to the performance of the overall system.

Deep Bed Horizontal Gravity Filter
Figure 13



FILTRATION LIMITS (WHAT'S ACCEPTABLE)
Table 1

A guideline for mineral oil applications is shown below relative to wire drawing applications.

Application	%Fines By Volume	Viscosity SSU @ 100°F	% Ash	% Moisture	% Ester
Rod Breakdown	<10%	<2,000 SSU	<20%	<0.1%	>15%
Inter. Wire Dwg.	<10%	<750 SSU	<20%	<0.1%	>10%
Fine Wire Dwg.	<7%	<400 SSU	<14%	<0.1%	>5%
Ultra Fine Wire Dwg.	<5%	<300 SSU	<10%	<0.1%	>5%

FIELD EXPERIENCE
Table 2

The table below reflects actual field results for various applications.

Customer	System	Tank Life to Recharge	Filtration
A	Rod Breakdown	12 Months	No
A	Rod Breakdown	32 Months	Yes
B	Fine Wire	6 Months	No
B	Fine Wire	12 Months	Yes

FIELD DATA
Table 3

Customer	Age	Volume Gals.	No. of Machines	Total HP	% Fines	Viscosity SSU	Draw	Clarifier Type
A	3 Years	14,000	4	1,200	5.9	1,673	Rod	Vacuum Filter
B	6 Years	17,500	4	1,900	7.7	1,258	Rod	Centrifuge
C	3 Years	5,000	1	600	1.5	1,060	Rod	Conveyor
D	5 Years	4,500	1	250	7.1	1,292	Rod	Cent./Conveyor
E	5 Years	8,000	11	1,480	6.5	864	Rod/Int	Cent./Conveyor
F	2 Years	7,000	4	1,200	1.8	860	Rod/Int	Conveyor
G	2 Years	2,250	1	400	0.5	750	Rod	Conveyor
H	2.5 Years	5,000	1	400	6.75	1,070	Rod	Centrifuge

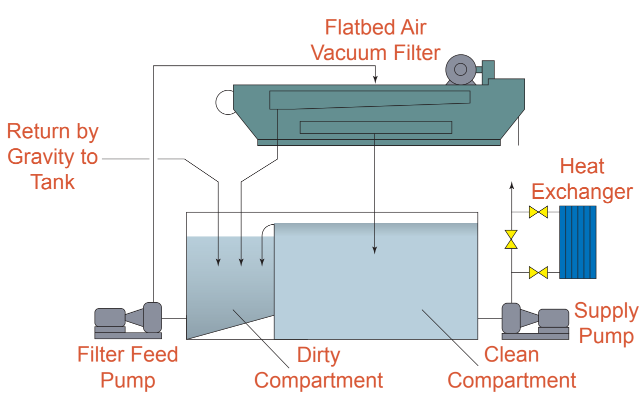
WATER SOLUBLE ALUMINUM WIRE DRAWING APPLICATIONS

This process has very unique filtration requirements as the aluminum oxide generates a grease like sludge.

Filtration was limited to intermediate and fine wire applications; however, recently water-soluble coolants are being used for rod breakdown wire drawing applications with a concentration typically in the range of 10-15%. Filtration for all applications is best accomplished using a flat bed air vacuum filter at a low GPM/ft^2 with specific features for the application.

The system concept shown in Figure #14 incorporates a two compartment tank with large clean and smaller dirty compartment. The concept allows for very efficient filtration, transferring coolant from the process to the filter. The concept eliminates surges within the filter bed allowing a consistent liquid level within the filter and allows an overflow of excess clean coolant back to the recirculation section of the reservoir tank below. The feature allows any free-floating material to be recirculated to the filter for removal. Additionally, when the supply pump is not in operation, the recirculation pump allows continuous filtration. The recirculation pump is relatively small capacity, essentially enough to establish an overflow between the clean section and recirculation section.

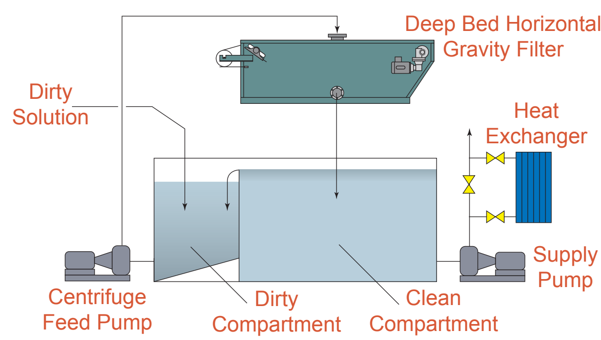
Two Compartment Tank With Vacuum Filter
Figure 14



It is essential that the reservoir tank be designed to allow a continuous overflow from the clean compartment back to the dirty section to remove any floating aluminum soaps.

Due to the unusual nature of the sludge collected from water-soluble lubricants, there are some chemical considerations to be made prior to designing a filtration system.

Two Compartment Tank With Deep Bed Gravity Filter
Figure 15



Aluminum fines react exothermically with water to form aluminum oxide. When exposed to the heat generated in this process, combustible materials can ignite.

Referring to Figure #14, an air vacuum-type media filter with a liquid extraction section will further dry the sludge-type material prior to the spent media being discharged. A deep bed horizontal gravity filter as shown in Figure #15 with an extented drying ramp may produce acceptable results if properly sized.

SUMMARY

While filtration of aluminum for mineral oil or water-soluble are somewhat difficult applications, success can be achieved by properly sizing a system relative to retention, component selection and type of clarifier utilized. In all types of aluminum wire drawing, filtration can be used to improve wire quality and extend lubricant life. It is very important to note that the cost of a filtration system can be recovered in reduced lubricant costs and improved wire production and quality.

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350 GPM (1325 LPM) Filter System for Two (2) Rod Breakdown Machines


240 GPM (912 LPM) Filter System for 2-Wire Rod Breakdown Machine


Collected Aluminum Solids from Centrifuge